2013 International Workshop on EUV and Soft X-Ray Sources
November 3-7, 2013 Dublin, Ireland

Development of Microwave Discharge Plasma for Extreme Ultraviolet lithography

Saya TASHIMA*, Masami OHNISHI, Waheed HUGRASS[1] and Hodaka OSAWA, Sho OE

Department of Electrical and Electronic Engineering, Faculty of Engineering Science, Kansai University, Japan

[1]School of Computing and Information Systems, University of Tasmania, Australia

INDEX

1) Introduction

•EUV lithography is a leading technology for the production of the next-generation. But there are still several problems to be resolved including the development of suitable EUV light sources.

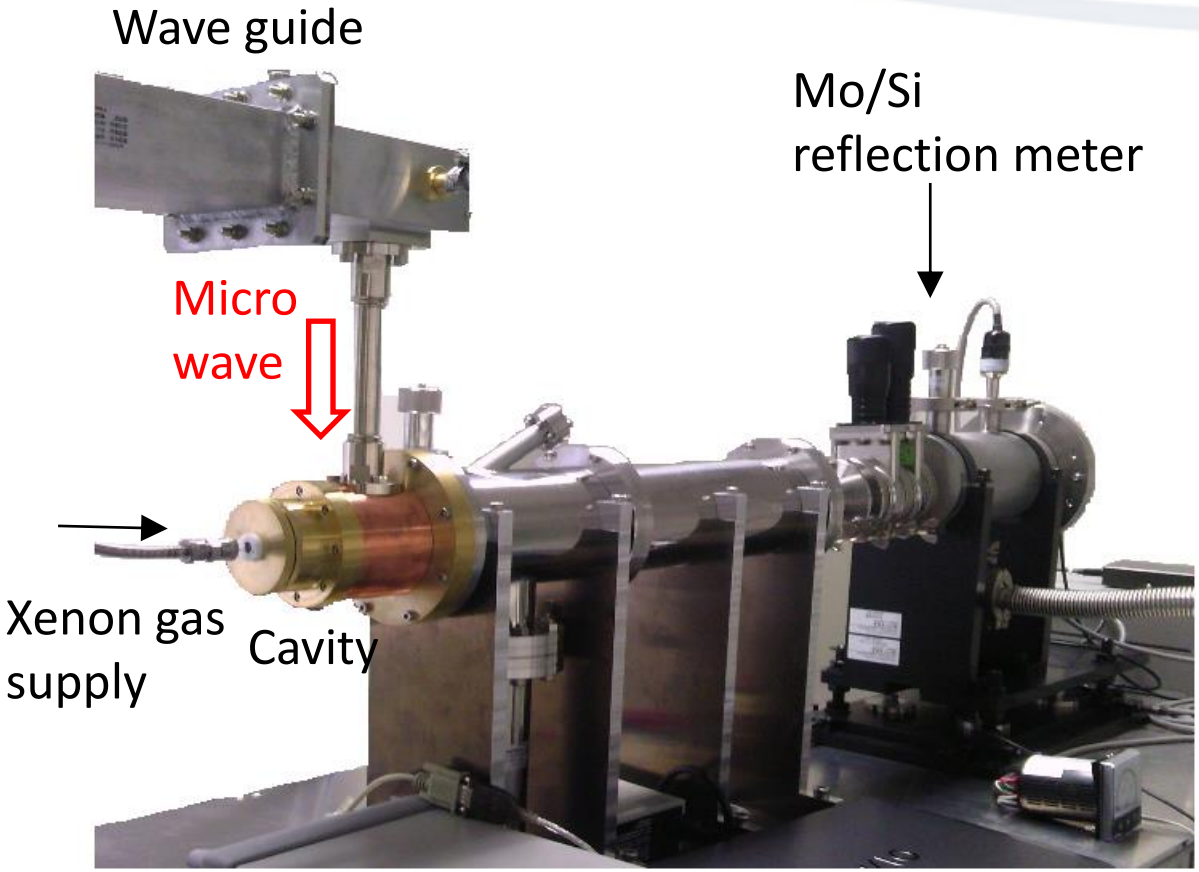
•The 13.5-nm EUV radiation is obtained from plasma by DPP and LPP sources mainly.

However,

1) The debris cause contamination of the EUV mirrors and the silicon wafers.

2) increasing of the time averaged power of EUV

1) Introduction



The microwave discharge produced plasma (MDPP) system.

1) Introduction

- **The microwave discharge produced plasma (MDPP) source does not produce debris at least in principle.**

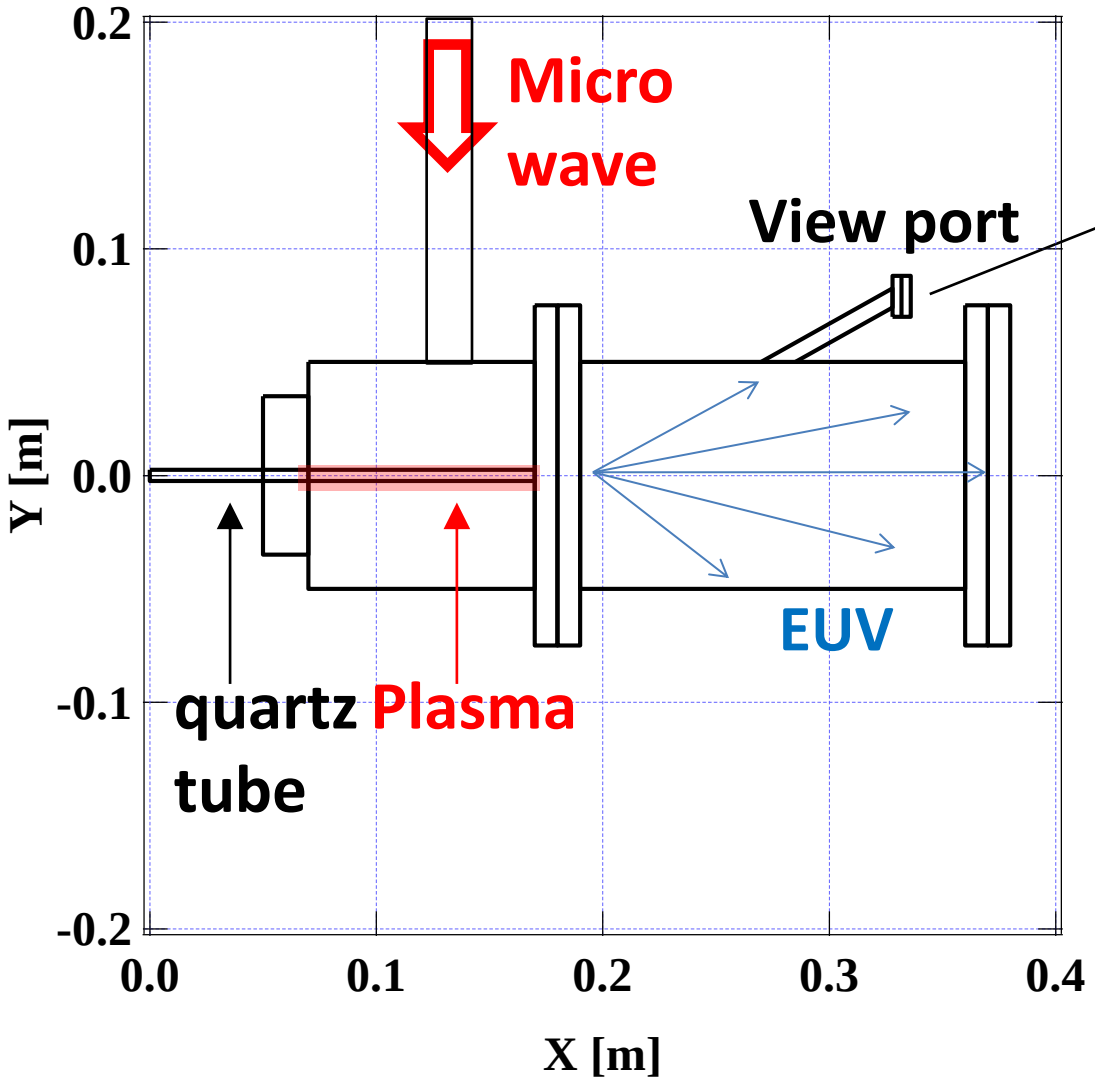
  Because it is electrode-less. Xenon is used as the working gas although it has a lower conversion efficiency compared to tin because it does not produce much contamination.

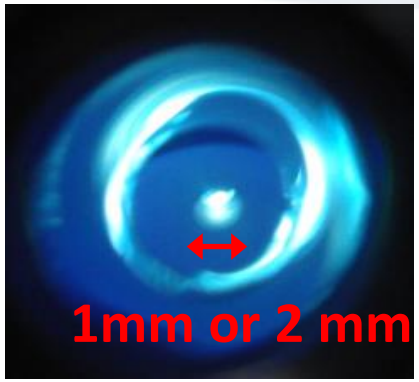
- **The duration of the EUV produced by the MDDP is about 3 orders of magnitude longer than LPP sources.**

  When the frequency of EUV output is same, the required peak radiation power is much lower

The experimental facility and the EUV measurement system are described and some preliminary experimental results are presented.

2) Microwave discharged produced plasma

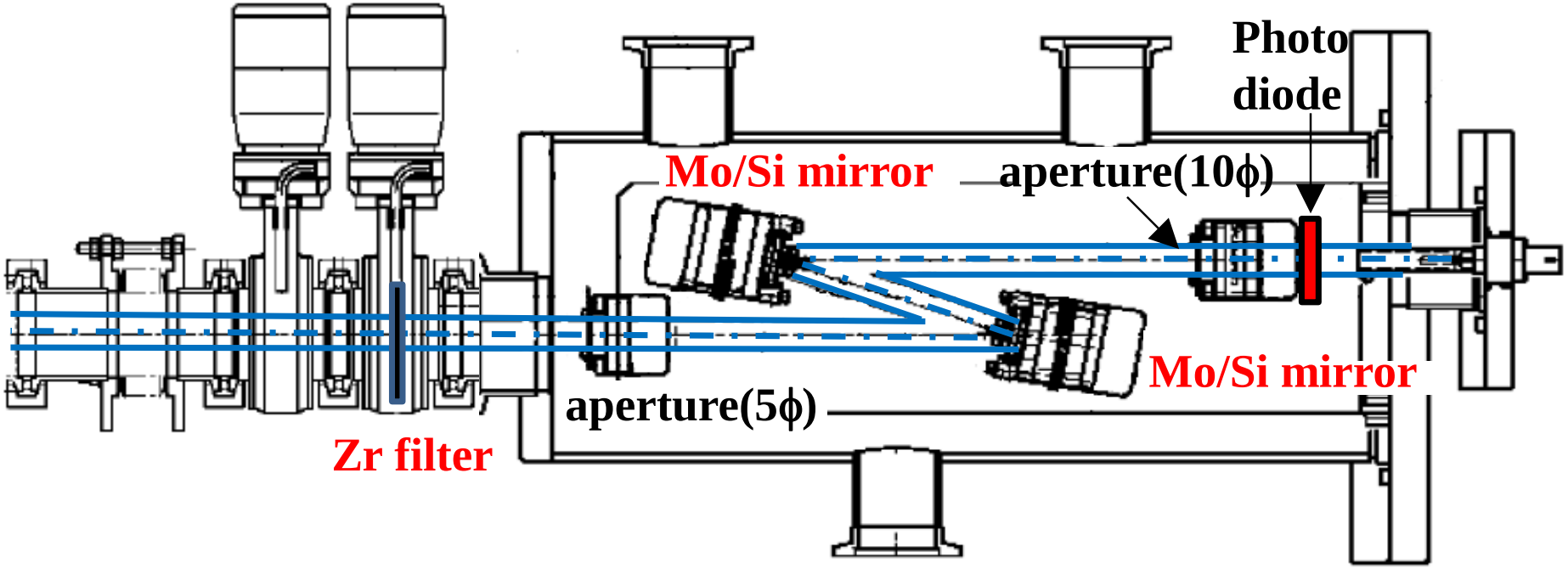




Visible light from view port

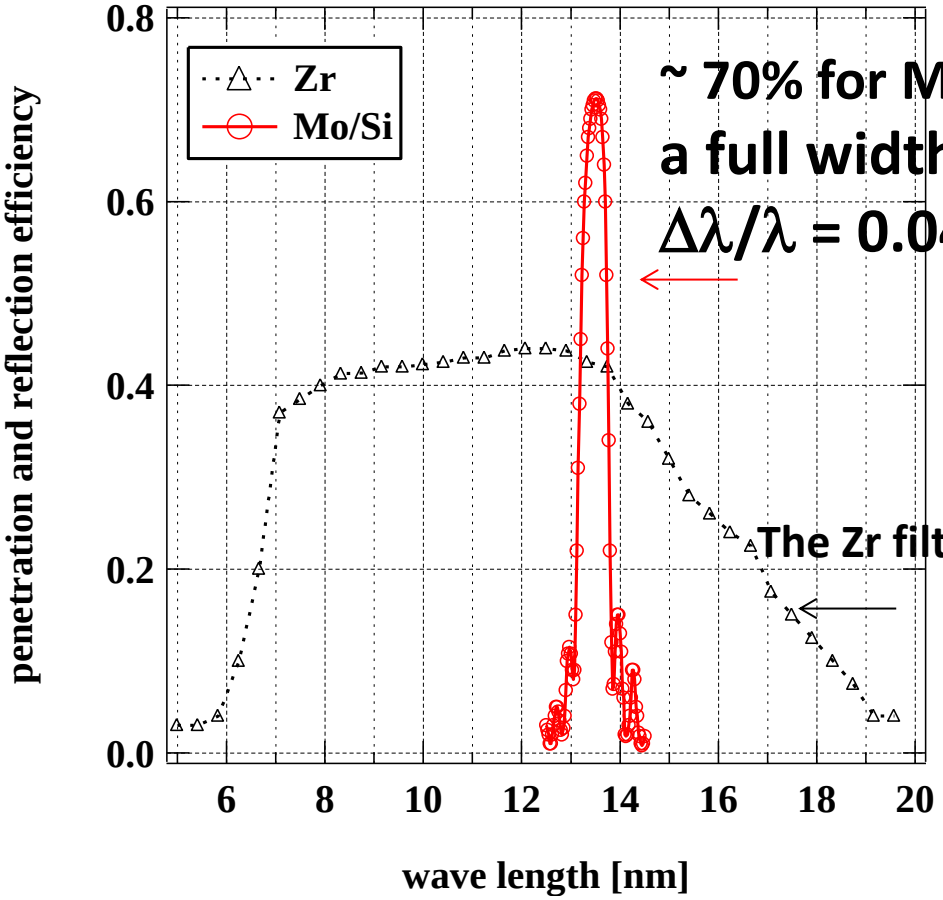
Magnetron : 2.45 GHz .
Maximum microwave power :
6 kW .
The cylindrical cavity mode : TM110.
The base pressure : 0.5-1 × 10^{-3} Pa.
Xenon gas pressure : ~1 Pa.

2) reflection meter



The reflection meter system, which consists of a Zr filter, two Mo/Si multi-layer reflection mirrors, apertures of ϕ5 and ϕ10, and a photo diode.

2) reflectivity of the Mo/Si & transmission of Zr filter



~ 70% for Mo/Si mirror

a full width-half maximum

$\Delta\lambda/\lambda$ = 0.048 at λ = 13.5 nm

The Zr filter cuts out the visible light

The reflectivity of the Mo/Si mirror and the transmission of the 100 nm Zr filter as functions of the wavelength.

2) Estimation of EUV power

$$W_{EUV}\ [W/2\pi str] = \frac{2\pi}{\Omega}\frac{\int_0^1 V\,dt}{R}\frac{1}{\langle R_d R_m R_m \rangle}\frac{1}{T_{zr}}\frac{1}{T_m}$$

Ω;Solid angle of reflection meter system (str)

V; output voltage of photodiode

R; Resistance in the amplifier

R_d; Responsivity of the diode (A/W)

R_m; Reflection ratio of EUV mirror (~0.6)

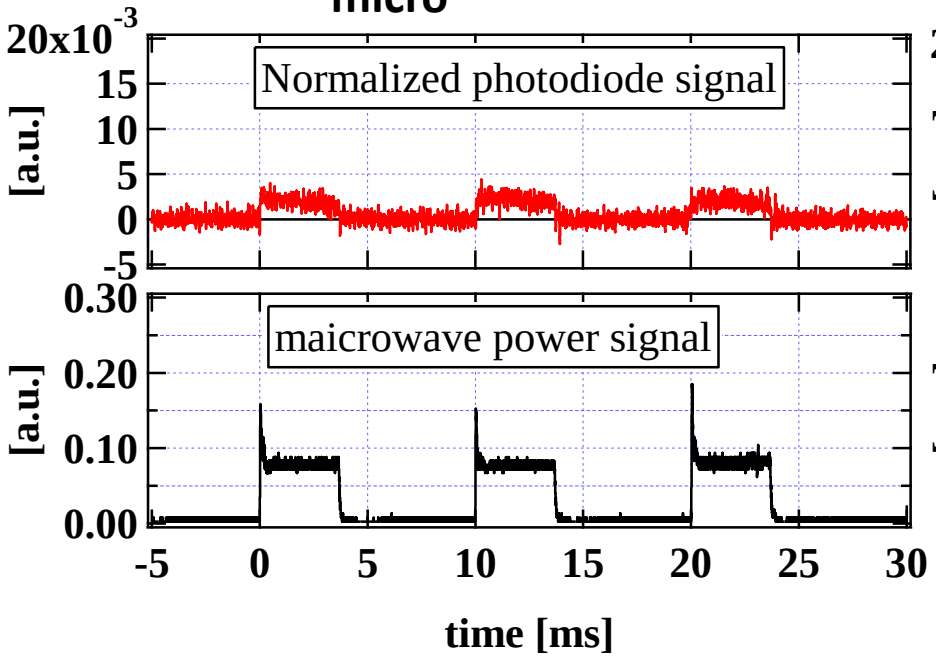
T_{Zr}; Transparency of Zr(Si_3N_4) filter (~0.12)

T_m; Transparency of filter(~0.36)

The calibration of the calorimeter was carried out by the standard E-Mon (Osaka university).

3) Experimental data

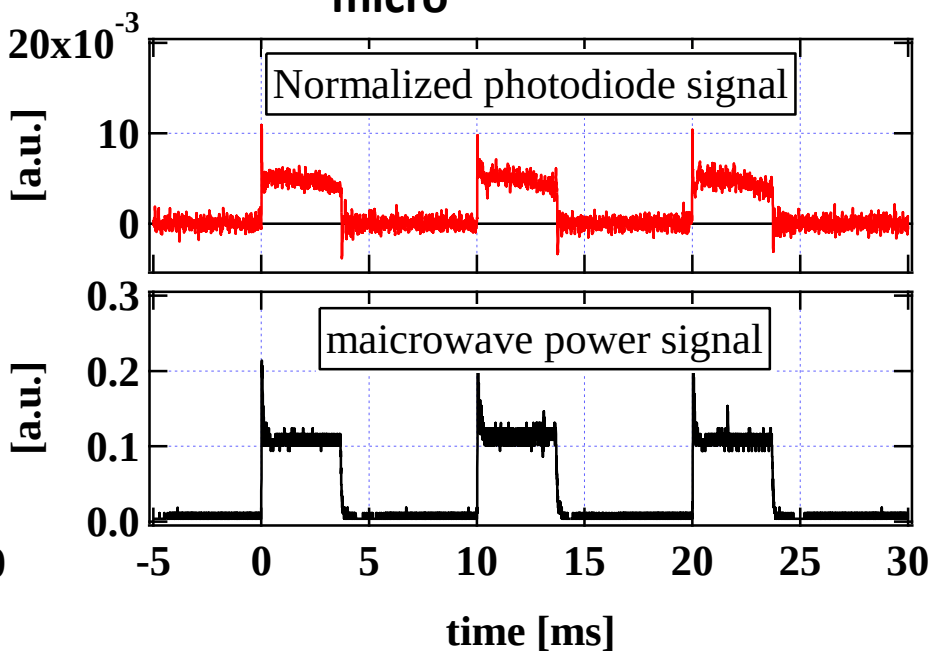
P_{micro} = 1000 W



Time averaged value ;

0.59 [W/2πstr]

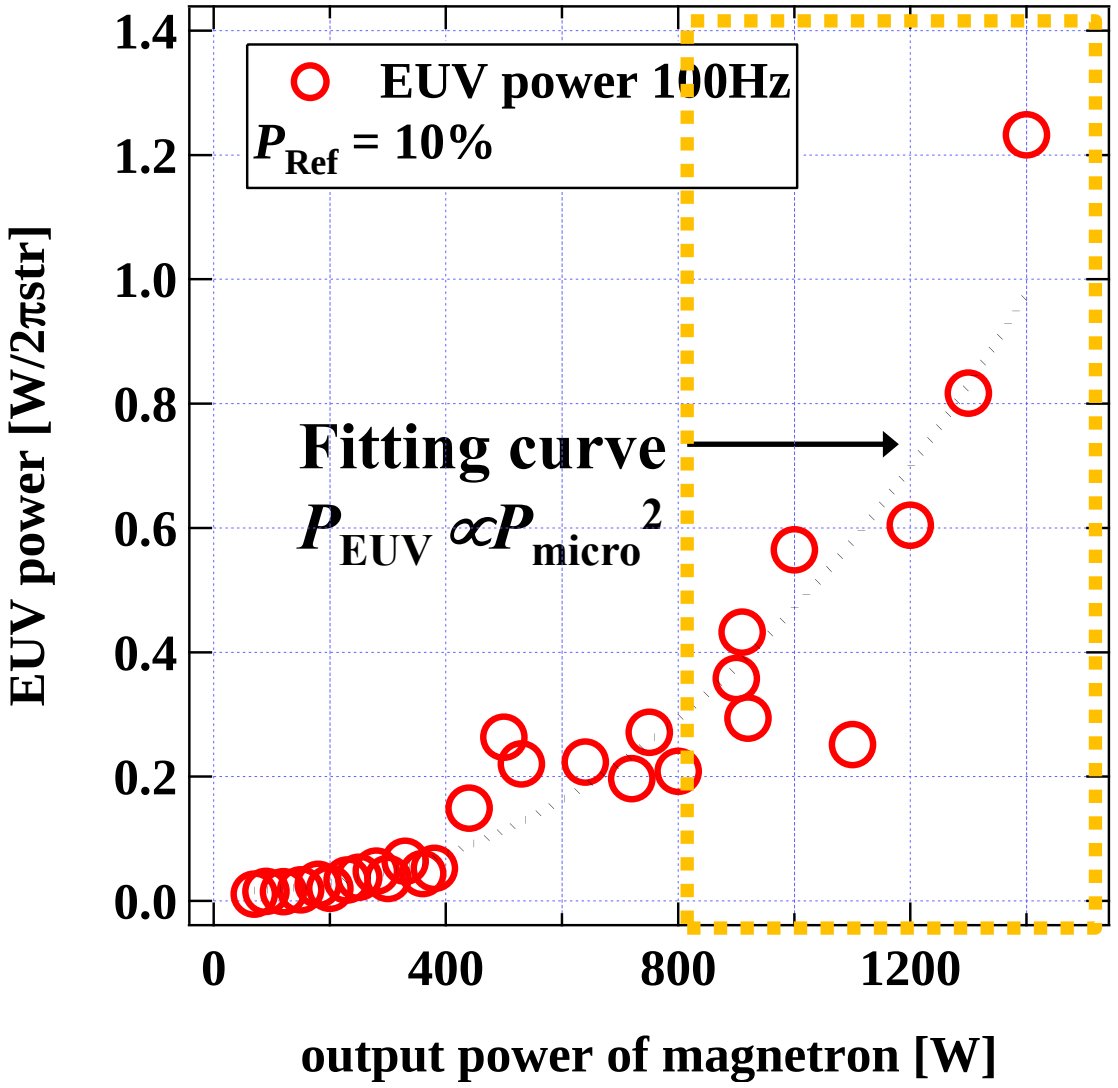
P_{micro} = 1300 W



Time averaged value ;

1.25 [W/2πstr]

3) Experimental data

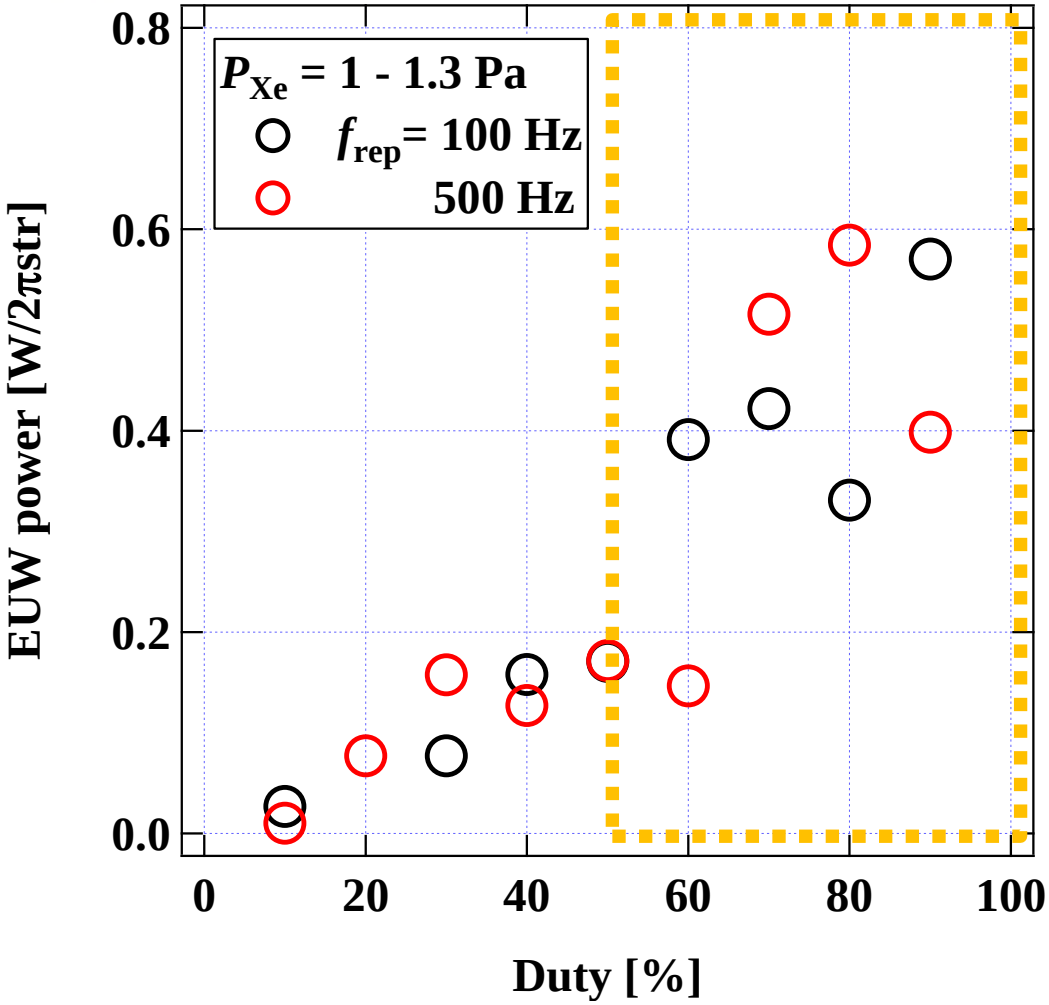


The EUV power (P_{EUV}) dependence of magnetron output power (P_{micro})
Reflection power ~ 10%

P_{EUV} increase with quadric function of P_{micro}.

At high microwave power discharge, The heat road of quart tube become serious.

3) Experimental data



The EUV power (P_{EUV}) dependence of duty of injected microwave.

P_{EUV} increase with almost linearity with duty.
At high duty, the heat road of quart tube also become serious.

4) Summary

- **MDPP source was developed to generate 13.5 nm extreme ultra violet (EUV) radiation for applications in photolithography.**

Experimental data show EUV power was 1.25 [W/2πstr] at repetition frequency was 100 Hz, and duty 10 %.

The EUV power (P_{EUV}) dependence of magnetron output power (P_{micro}) of 2.45 GHz shows P_{EUV} increase with quadric function of P_{micro}.

4) Future plan

1) **Improvement of cooling system.**
   The performance of the present facility is limited mainly by the magnetron power and the insufficient cooling system of the quart tube.

2) **Reducing the size of plasma.**
   Reducing the size of light source.
   Increasing the microwave power density in plasma.

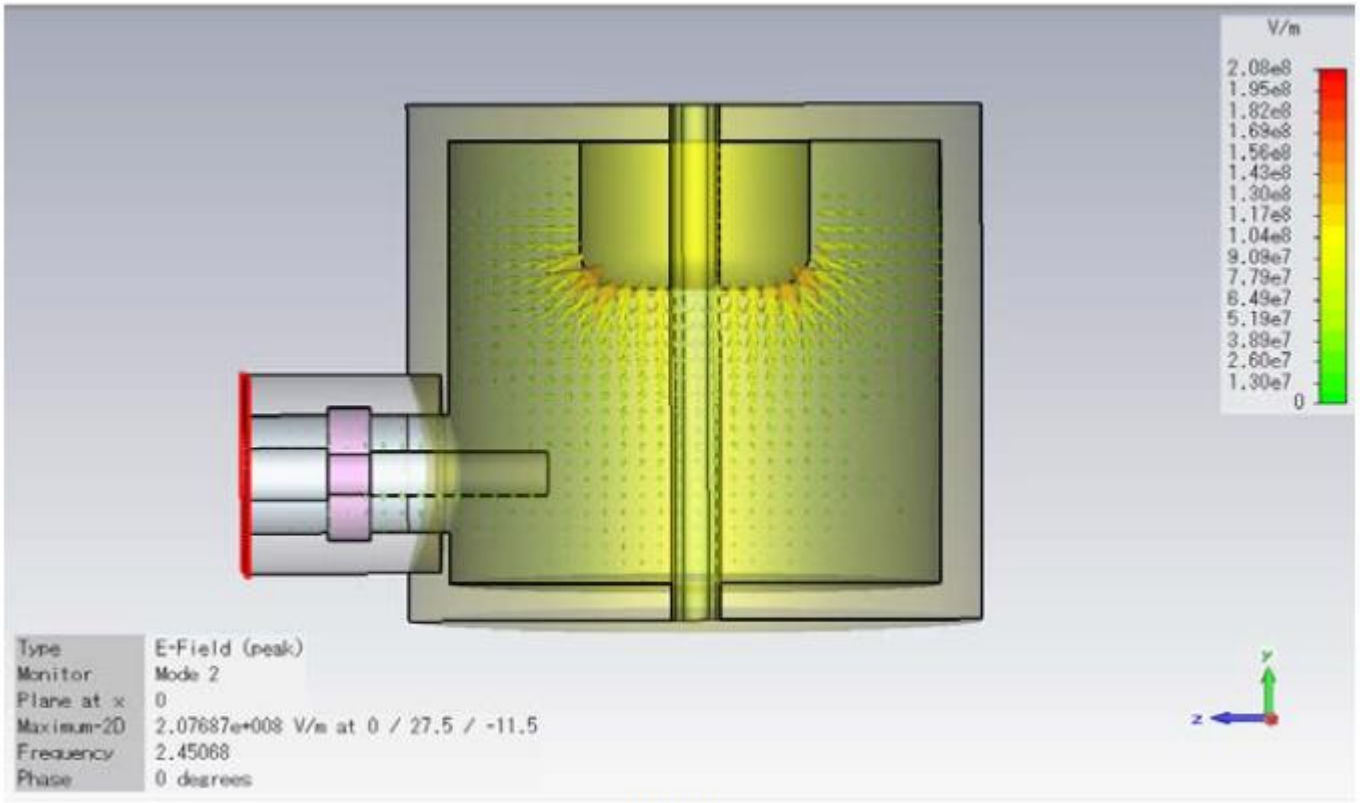
Acknowledgment
This study is supported by the START project by the Japanese Ministry of Education, Culture , Sports, Science and Technology.

Thank you!

Calibration of reflection meter

E-field of TM010 mode

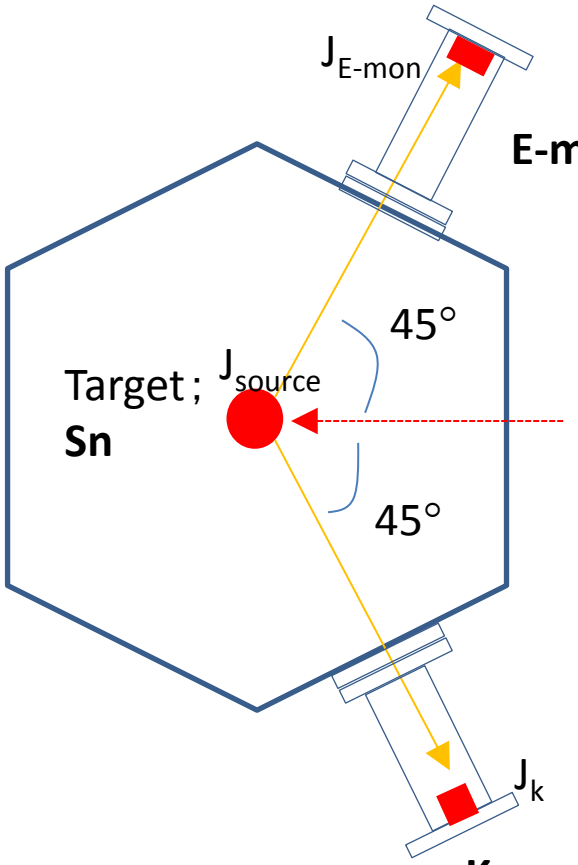
Q ~ 8000T



図・2

Calibration of reflection meter

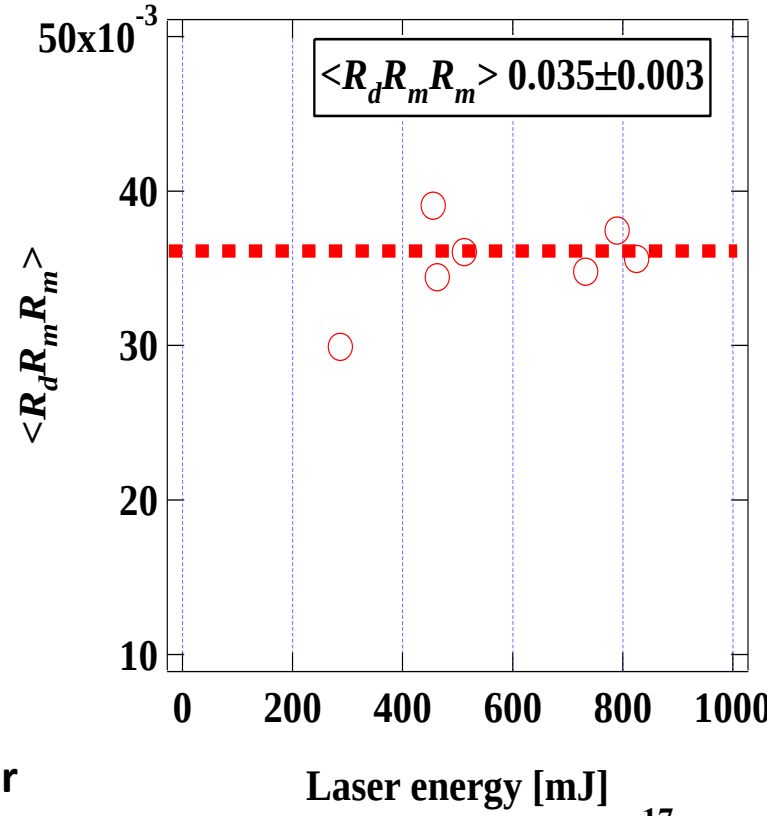
The calibration of the calorimeter was carried out by the standard E-Mon.



E-mon (Osaka university)

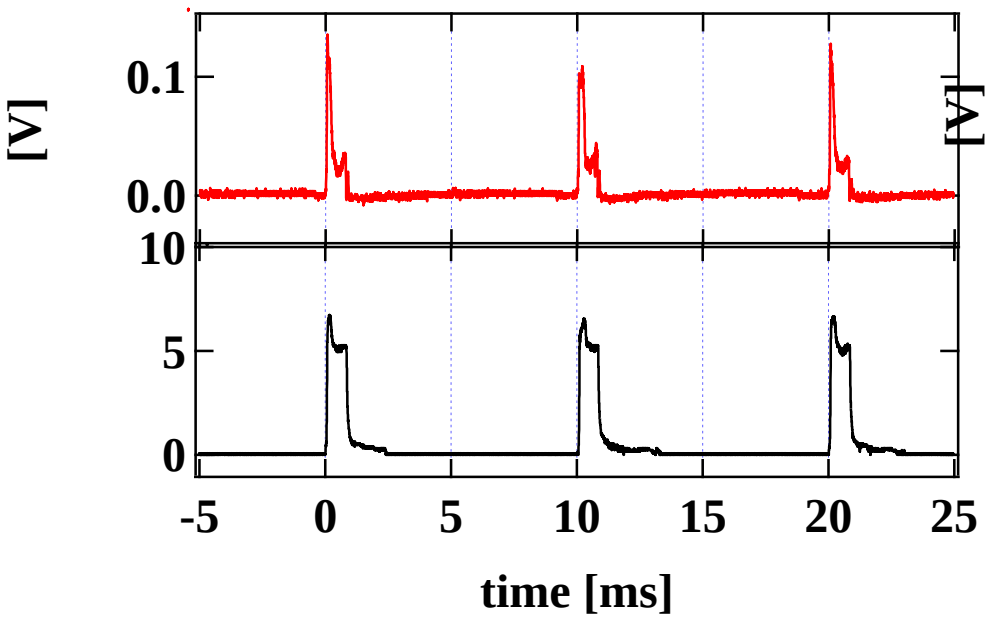
Laser 500mJ 10ns

Kansai university reflection meter



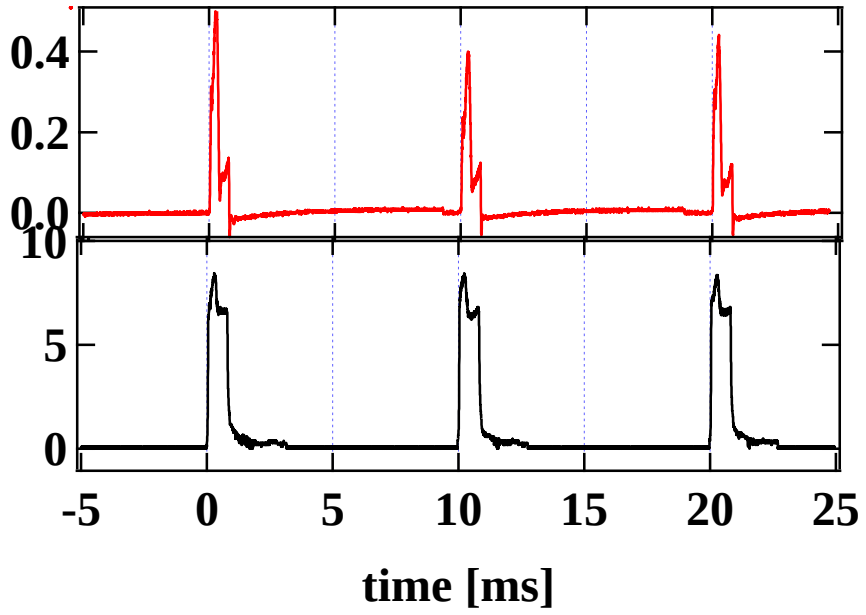
Experiment data (at High Q condition)

P_{micro} = 370 W



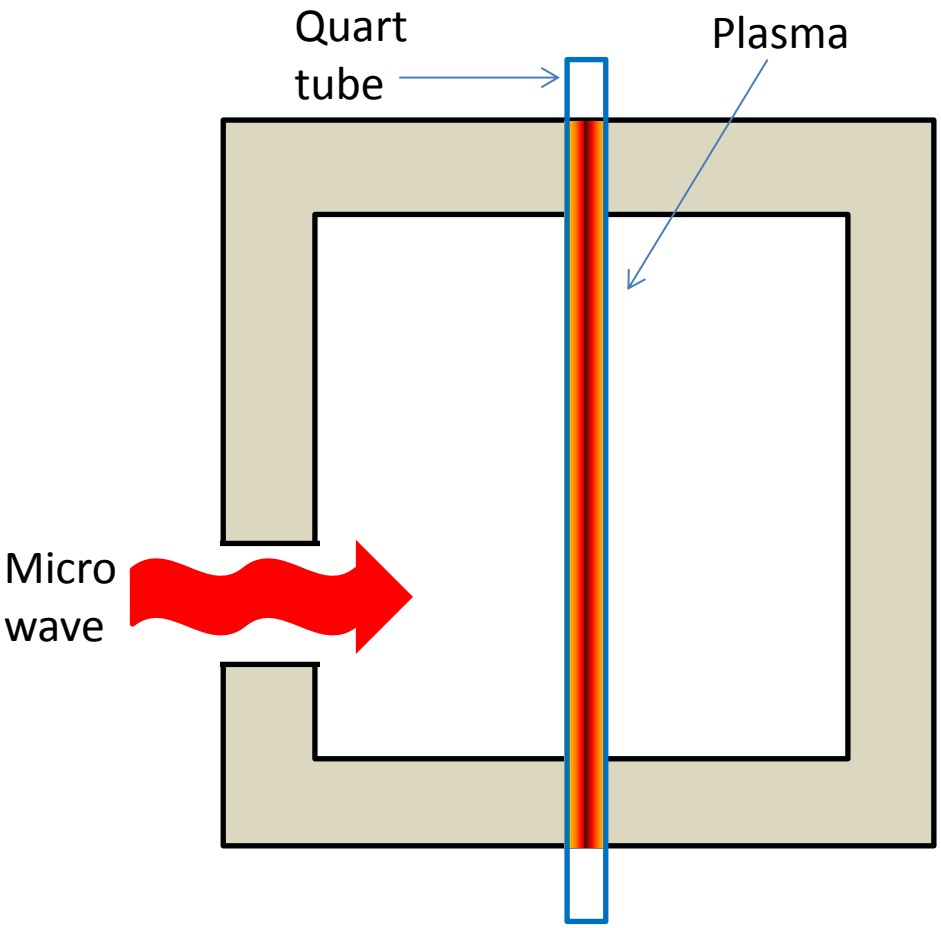
0.8 [W/2πstr]

P_{micro} = 470 W



2.7 [W/2πstr]

- $E = \pi A(NA)^2$
- A ; 光束断面積
- πNA^2; $NA = \sin\theta$
- R = 1.5mm θ = 10°
- E=3.14*3.14*1.5*1.5*(sin10°)^2=3.8 mmSr


Quart
tube
Plasma
Micro
wave


Ne Gas